

DRAFT
VADOSE ZONE VOC CLEANUP STANDARD
For SVE Systems at CERCLA sites

Regional Water Quality Control Board - Central Valley Region

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Introduction

Remedial objectives (cleanup levels) specific to volatile organic compound (VOC) contamination in the vadose zone are necessary to prevent degradation of groundwater and cease continued release of VOCs to the groundwater. Continued release of VOCs from soil to groundwater can hamper, or even prevent, the achievement of groundwater cleanup goals. In California, vadose zone cleanup actions should promote attainment and/or maintenance of background water quality, or the best water quality that is reasonable to achieve if background levels cannot be restored. Vadose zone cleanup levels must protect designated beneficial uses of water as measured by water quality objectives set forth in the Water Quality Control Plan for the California Regional Water Quality Control Board, Central Valley Region (Basin Plan). If vadose zone cleanup cannot be achieved to the degree that background water quality is restored and maintained, an alternate vadose zone cleanup level may be established to protect groundwater, such that water quality objectives will not be exceeded. In order to achieve these requirements, the vadose zone shall be cleaned up to the maximum degree that is technically and economically feasible.

The objective of protecting background water quality is based on State Water Resources Control Board Resolution No. 92-49, which contains policies, requirements and procedures for Regional Water Board oversight of investigation and cleanup and abatement activities to address all types of discharges, or the threat of discharge, subject to Section 13304 of the Water Code. Pursuant to this Resolution, the Regional Water Boards must ensure that dischargers are required to cleanup and to abate the effect of discharges. Specific language requires this cleanup and abatement to promote attainment of background water quality, or the highest water quality which is reasonable, given economic and technical feasibility, if background levels of water quality cannot be restored. This technical and economic evaluation should be performed in a Feasibility Study completed prior to installation of a vadose zone cleanup system. Any cleanup less stringent than background water quality shall be consistent with maximum benefit to the people of the state and shall not unreasonably affect present and anticipated beneficial uses of such water, i.e. should result in attainment of water quality objectives. The Regional Water Board also realizes that many aspects of this process will involve professional judgement on the part of both the discharger and Board staff, and that discussion will be required on a site-by-site basis.

Vadose Zone VOC Cleanup Standard

For cleanups of VOCs overlying groundwater in excess of the water quality objective, the vadose zone cleanup standard has been achieved when:

Residual VOC contaminants in the vadose zone no longer cause concentrations in the leachate discharging to groundwater to exceed water quality objectives.

An SVE system should be operated until it can be demonstrated that the vadose zone VOC cleanup standard has been met. When the cleanup standard has been met, the discharger must evaluate the technical and economical feasibility of continuing remediation. Only when the discharger shows that it is no longer technically or economically feasible to remove VOCs from the vadose zone can the SVE system be shut off.

Designated waste is defined in Water Code Section 13173 as the level of a contaminant in soil (either in the adsorbed phase, dissolved in the pore water, or in the vapor phase) that could be released (i.e. in leachate) in concentrations exceeding applicable water quality objectives. To determine what concentrations would occur in a leachate from contaminated soil, appropriate leachability and attenuation factors must be considered. For VOCs in soil, this would include such factors as the physical and chemical composition and properties of the soil matrix, its organic matter content, the soil moisture content, and the distance of the contaminants from groundwater, as well as other factors. Appropriate fate and transport computer modeling programs can be used to assess these site-specific variables and estimate the leachate concentrations at the water table, given a certain VOC concentration and mass in the vadose zone.

Technical and Economic Feasibility Evaluation

Normally, a technical and economic feasibility evaluation is done in the Feasibility Study to determine the soil cleanup level to protect groundwater between background concentrations and the water quality objective level(s). However, with SVE, as with other in situ treatment technologies, the effectiveness of the remedial technology is not usually sufficiently known prior to system implementation to assess if background may be achievable. In contrast, an ex-situ remedial technology, such as excavation and off-site disposal, can be more readily assessed in the Feasibility Study, based on field data of the contaminant's distribution.

The Regional Water Board realizes that attainment of the cleanup standard is not always possible, and there must be a way to determine if SVE system shutoff is acceptable when the SVE system has not, and apparently will not, achieve the cleanup standard. This technical and economic feasibility evaluation, which is functionally equivalent to the Technical Impracticability waiver process available under CERCLA, provides an opportunity for the discharger to demonstrate that the system should be shut off in the event that the contaminants cannot be reduced to the acceptable levels as stipulated by the cleanup standard.

When the cleanup standard has not, and probably cannot, been met, a technical and economic feasibility evaluation shall be used to help determine if the soil vapor extraction (SVE) system can be curtailed or shut off completely. The discharger shall evaluate the VOC concentrations in leachate, the extent of the impact of leachate to groundwater and the additional costs associated with additional removal of VOCs. The goal is to determine and compare cost differences between VOC mass removal by groundwater extraction and treatment after the VOCs have leached to groundwater, continued SVE operation to remove VOCs from the vadose zone, and SVE enhancements that may improve the efficiency and cost-effectiveness of the existing SVE system.

The following factors must be assessed to demonstrate compliance with the cleanup standard and the technical and economic feasibility portion of SWRCB Resolution No. 92-49:

- a. Whether the residual VOC contaminants in the vadose zone no longer cause concentrations in the leachate discharging to groundwater to exceed water quality objectives

The SVE system shall be designed and operated to remove VOCs to the level that remaining VOC contaminants no longer cause concentrations in leachate to exceed the aquifer cleanup level. Modeling may be used to predict the leachate concentrations. If it is demonstrated that it is not technically and economically feasible to remove additional mass beyond the cleanup standard level, then the standard has been met and the system may cease operation.

- b. Whether the mass removal rate has stabilized at a level approaching the asymptotic level following one or more temporary shutdown periods (no rebound in concentration), and after the SVE system has been appropriately optimized.

The concentrations of VOCs in the vapor phase and mass removal rates, from individual extraction and vapor monitoring wells and from the SVE system as a whole, are expected to decline over time and approach an asymptote. At this point an evaluation of rebound of VOC concentrations in individual wells should be conducted. If concentrations rebound, then SVE operation should be continued, possibly at only selected wells. It is reasonable to assume that multiple "pulsing" episodes of the SVE system may be required, and that multiple rebound evaluations may be necessary, based on site-specific conditions. Once the concentrations are stable and no longer rebound significantly, a vapor and leachate transport model should be used to evaluate potential impacts to groundwater.

System optimization is a critical aspect to proper extraction and treatment of VOCs at a site. The system should be operated and optimized with a goal of maximizing mass removal and mass removal rates, again both from individual extraction wells and the system as a whole. This may involve an evaluation of the extent of contamination remaining with respect to modifying the extraction well field to optimize extraction. For example, in a case where a hot spot persists about one or more wells, only these wells would be necessary for continued extraction. Other optimization measures may include adjusting flow rates and cycling different portions of the

wellfield on and off. The responsible party must demonstrate a good faith effort to optimize the SVE system.

It should be noted that there is not yet clear agreement between the various regulatory agencies and the regulated community about what specifically constitutes system optimization, mass removal to asymptotic levels, or significant rebound in in situ mass concentrations during pulsing periods. Additionally, little definitive guidance is available to help clarify these concepts, although various agencies are currently working on these issues. As such, agreement on how to evaluate these concepts is usually undertaken on a site by site basis, and involves considerable professional judgement of the various parties involved. Because of this lack of adequate guidance and consensus, we have left the evaluation of these topics in this guidance general in nature.

- c. The additional cost of continuing to operate the SVE system when mass concentrations have approached asymptotic levels.

The responsible party must determine and present accurate costs associated with continued operation of the existing SVE system after concentrations in the soil vapors (in the extraction wells, the soil vapor monitoring wells and the system as a whole) have approached asymptotic levels. These costs will be used in the technical and economic feasibility evaluation as noted below.

- d. The predicted effectiveness and cost of further enhancements to the SVE system (e.g., additional vapor extraction wells, air injection) beyond system optimization, to improve operation of the remedial system and to remove additional VOCs.

The responsible party must consider system enhancements such as steam or hot air injection, additional wells, etc. which might increase the effectiveness of the SVE system. In some instances, these enhancements might be necessary to overcome limiting site conditions, and may be more cost-effective than installing groundwater treatment systems or running groundwater remedial systems for an extended period of time. Examples of system enhancements can be found in the EPA document *Analysis of Selected Enhancements for Soil Vapor Extraction*, EPA-542-R-97-007, September 1997.

- e. Whether the cost and/or duration of groundwater remediation will be significantly more if the residual vadose zone contamination is not cleaned up.
- f. The incremental cost over time of vadose zone remediation compared to the incremental cost over time for groundwater remediation on the basis of a common unit (e.g., cost per pound of TCE removed) provided that the underlying groundwater has not reached aquifer cleanup levels.

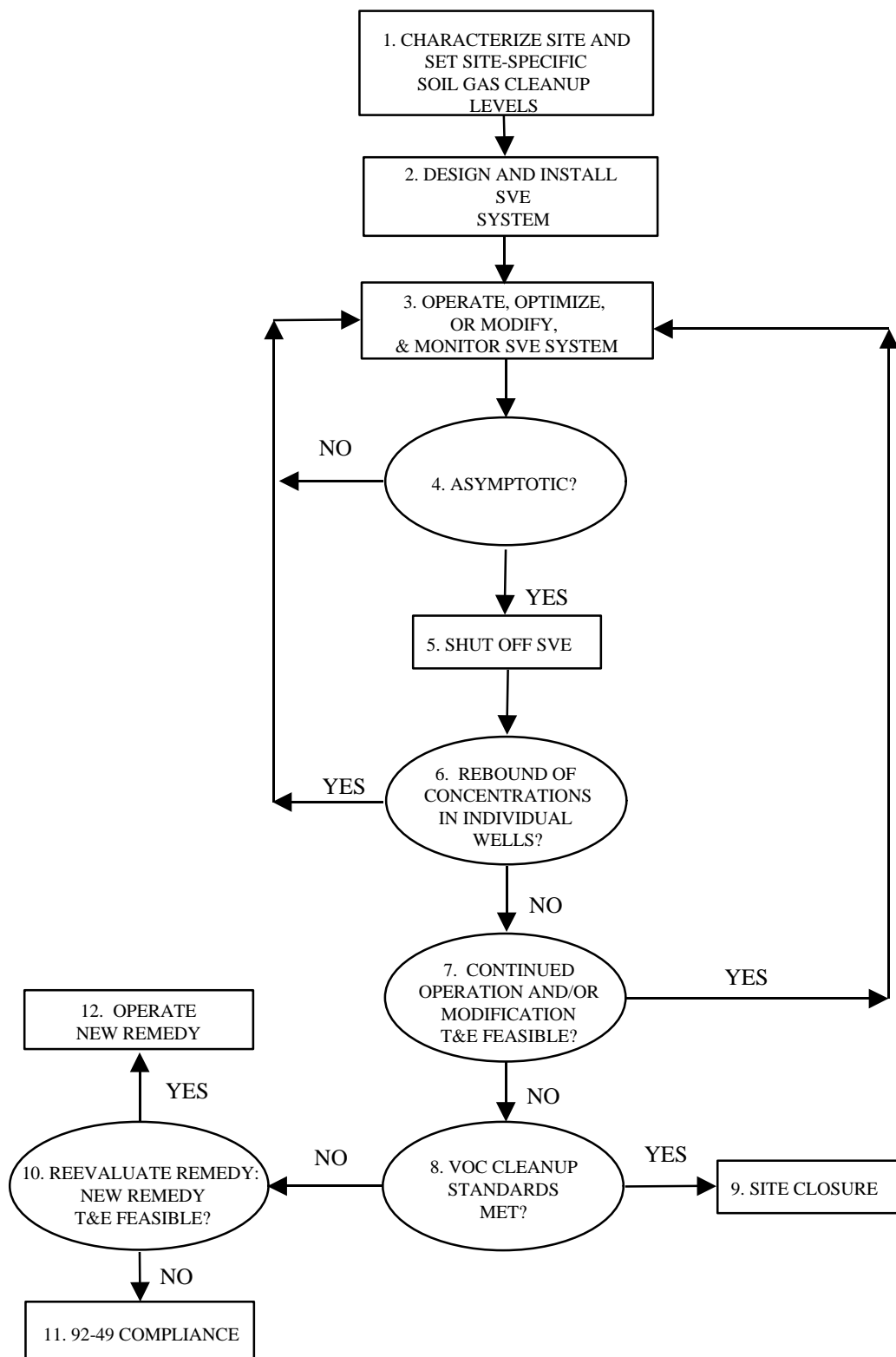
As discussed in item "c" above, the responsible party must determine and present accurate costs associated with continued operation of the existing SVE system after mass removal rates and

concentrations in the extracted soil vapors have approached asymptotic levels. These costs will be used in the technical and economic feasibility evaluation to compare costs to treat the remaining mass through either continued SVE operation or groundwater pump and treat or a combination thereof. This allows the most cost effective and timely response action to be determined. If it is demonstrated to be more time- and cost-effective to let remaining mass leach to groundwater to later be extracted and treated via a groundwater pump and treat system, then the SVE system could be shut down. If the leaching impact to groundwater significantly extends the cleanup time for, or adversely affects the success of, the groundwater remediation the responsible party should continue SVE operation.

It is difficult to accurately predict with certainty the additional time that would be needed to meet aquifer cleanup levels. One can directly determine the current cost of VOC removal per pound by the existing groundwater remedial system, which is expected to only increase as concentrations in the groundwater decrease over time. SVE operation should continue if the incremental cost over time of vadose zone remediation is much less than the incremental cost over time for groundwater remediation. SVE system enhancements should be implemented if determined to achieve a more cost effective or timely cleanup.

SOIL GAS REMEDIATION FOR VOCs

RWQCB-CVR



DRAFT
Narrative Explanation for Soil Gas Based Remediation for VOCs Flowchart
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1. Characterize Site and Set Soil Gas Cleanup Levels. Eventual curtailment and shut down of SVE at a site also includes the underlying presumptions that the site has been adequately characterized, the SVE system design is appropriate for the site and appropriate performance monitoring has been conducted at the site on a regular basis. Depending on the circumstances, numerical cleanup levels can either be: 1) set at background; or 2) determined by a simple equilibrium model such as the Henry's Law constant for the contaminant multiplied by the groundwater cleanup level or water quality objective; or 3) by more complicated modeling such as VLEACH. In either case numeric cleanup levels should be set whose goal is to either meet the VOC cleanup standard or background.

2. Design and Install SVE System. Once the site has been adequately characterized, the SVE system may be designed and installed at the site. Appropriate operation and monitoring schedules should also be formulated during the design stage.

3. Operate, Optimize, Or Modify, and Monitor SVE System. Once the system is installed, the "routine" operation, optimization, and monitoring cycle begins. Appropriate operation and monitoring schedules as previously agreed to should be implemented. System optimization may also be required after the system has been operated for a long enough period to establish "baseline" conditions. Optimization may include such typical measures as shutting off or adjusting flow rates from certain extraction wells based on the measured contaminant concentrations in both the influent to the treatment system and the contaminant concentrations in the individual extraction wells and vapor monitoring points. If this is the second or more iteration of this step, modifications to the system may need to be implemented. These modifications may include system enhancements, such as heated air injection or blower replacement, or expansion of the system, such as the installation of additional extraction wells and monitoring points. Similarly, the number of extraction wells may be reduced if some parts of the site have been suitably cleaned up, and only continued remediation of "hotspots" is required.

4. Asymptotic? After the system has been operated for a suitable time and concentrations and mass removal rates are declining, a preliminary evaluation of system shutoff should be performed. Has an asymptote been reached based on historic and current VOC concentrations in both the combined influent to the system and in individual extraction wells and soil vapor monitoring points? Has an asymptote been reached based on cumulative mass removed expressed as a function of time? If the asymptotes have not been reached, the system should continue to be operated. If the asymptotes have been reached, for all extraction wells and the combined vapor influent, the system should be shut off to determine if rebound of the contaminants into the vapor phase will occur.

5. Shut Off SVE. Once asymptotic levels been reached, the system should be shut down for a period of time to allow equilibrium of the contaminant(s) in the subsurface between the soil gas, adsorbed, and dissolved phases. The amount of time required for the subsurface to re-equilibrate in the shut-down period will vary from site to site, depending on the lithology of the site and the contaminants present. Periodic monitoring of the contaminant concentrations in the soil vapor extraction wells and the soil vapor monitoring points should be conducted to gather data on rebound.

6. Rebound of Concentrations in Individual Wells? If the concentrations of contaminants in the soil vapor in individual wells rebound, additional operation of the SVE system is warranted. If the concentrations of contaminants in the soil vapor do not rebound, an evaluation of the attainment of the VOC cleanup standard can be made.

7. Continued Operation and/or System Modifications Technically and Economically Feasible? An evaluation of continued operational and cost effectiveness of the system is warranted after asymptotes are reached during the continued operation of the system. This evaluation is warranted to comply with State antidegradation requirements regardless of the cleanup levels attained. If cleanup levels have been met, this evaluation should still be performed to determine if it is technically and economically feasible to remove additional mass and further reduce groundwater remediation costs. This technical and economic evaluation should include the following:

- a. The additional cost of continuing to operate the SVE system when mass concentrations have approached asymptotic levels.
- b. The predicted effectiveness and cost of further enhancements to the SVE system (e.g., additional vapor extraction wells, air injection) beyond simple system optimization, to improve operation of the remedial system and to remove additional VOCs.
- c. Whether the cost and/or duration of groundwater remediation will be significantly more if the residual vadose zone contamination is not addressed.
- d. The incremental cost over time of vadose zone remediation compared to the incremental cost over time for groundwater remediation on the basis of a common unit (e.g., cost per pound of TCE removed) provided that the underlying groundwater has not reached aquifer cleanup levels.

This step should also evaluate the predicted effectiveness and cost of further enhancements to the SVE system (e.g., additional vapor extraction wells, air injection, etc.) beyond system optimization, which should occur throughout operation of the remedial action, to remove additional VOCs. If modifications or enhancements will increase the technical and economic feasibility of continued operation of the system in a cost-effective manner, then these modifications or enhancements should be made to the system.

If the above evaluation indicates that further operation of the existing, or modified, system is technically and economically feasible, then continued operation of the system should be conducted. If it is not technically and/or economically feasible to operate the existing or modified system, the remedy should be re-evaluated.

8. VOC Cleanup Standard Met? Has the VOC cleanup standard been met after the system has been shut-off for a period of time and the constituents in the vadose zone allowed to re-equilibrate? Are the predicted leachate concentrations discharging to groundwater within acceptable limits? If the VOC cleanup standard has not been met, an evaluation of whether or not it is economically and technically feasible to continue remediation using an alternative remedy should be conducted. If the VOC cleanup standard has been met the site can be closed.

9. Site Closure. At this point the site may be closed as it has been determined that: 1) contaminant mass removals have approached asymptotic levels; 2) there is no rebound of contaminant concentrations in the wells; 3) it not technically and/or economically feasible to remove additional mass; and 4) the VOC cleanup standards have been met.

10. Reevaluate Remedy. If the technical and economic feasibility evaluation performed above indicates that it is not economically and technically feasible to remove the remaining contaminants using the existing or modified system, then the site remedy should be re-evaluated. An evaluation should be conducted to determine if another remedy, other than SVE, is technically and economically feasible for the site. In some cases an alternate remedy may be shown to be economically and technically feasible. If an alternate remedy is feasible, that remedy should be instituted. If an alternate remedy is not feasible, the State can determine that compliance with Resolution 92-49 has been met (which is equivalent to the site being granted a Technical Impracticability waiver under CERCLA).

11. 92-49 Compliance. After all efforts have been expended to remediate the site to the extent technically and economically feasible, and the VOC cleanup standard has still not been met, the State can determine that the discharger has complied with SWRCB Resolution No. 92-49, and no additional soil cleanup will be required. Compliance with the cleanup to the maximum extent technically and economically feasible provisions of SWRCB Resolution No. 92-49 is analogous to the technical impracticability waiver available under the CERCLA program. If VOCs continue to leach into the groundwater, however, additional remediation may be required for the groundwater, even though no additional soil cleanup is required at the site.

12. Operate New Remedy. The newly selected remedy should be implemented as appropriate if the reevaluation of the site remedy indicates that another remedy is suitable to cleanup the VOCs in the vadose zone. After implementation of the new remedy, evaluation cycles similar to those described above should be implemented to determine if the new remedy has cleaned up the VOCs to the extent technically and economically feasible and to determine if the new remedy has met the VOC cleanup standard.